LONG TERM STEWARDSHIP
CONTAMINATION CONTAINMENT AND CONTROLS

January 21-22, 2002
Dallas, Texas

Flip Chart Notes

1. Vision statement discussion

- Concept of Failure
  - Triggered by catastrophic event
  - Inadequate design
- Understanding “how” systems perform/change over time
- No current system to eliminate need for stewardship
- Not currently integrated w/ other LTS elements

  “Secrets of nature provide clues for the future”
- Package existing S&T so that it’s usable/available to users
- Event analysis, early indicators, reponse

2. Draft vision statement

Long-term – Implement CC&C systems integrated with LTS needs to enable effective stewardship and reduce cost and risk for future generations.

By 2008 – CC&C systems will (1) incorporate analysis of events that compromise system integrity, early indicators of change, and responses; (2) incorporate an understanding of natural processes that can affect future performance; and (3) integrate engineered, natural, and human system and incorporate new information over time.

3. CC&C Activities

1. Limit Contaminant Toxicity and Mobility
2. Limit Intrusion, Release, Transport, and Exposure
3. Accommodate Environmental Change
4. Monitor and Evaluate System Performance
5. Maintain System Performance
6. Communicate System Performance Information
7. Improve System Designs *[added at end of working group session]*

4. CC&C Capabilities (6 Sheets)

- Limit Contaminant Toxicity and Mobility (Sheet 1)
  - Understand contaminant/biogeochemical/thermal interactions (e.g., redox, KDs, time dependence, coupled processes
  - Scale from lab-scale to field-scale
  - Predict and verify system effectiveness
  - Engineer biogeochemical environment

- Deliver stabilizing and detoxifying agents

– Limit Intrusion, Release, Transport, and Exposure (Sheet 2)
  - Understand and characterize site-specific intrusion, release, transport, and exposure (including movement through heterogeneous systems)
  - Design, build, and operate CC&C systems (e.g., pump & treat, funnel & gate, surface/subsurface barriers, design-to-failure points)
  - Scale-up in space and time (including accelerated testing)
  - Understand and mimic natural systems

– Accommodate Environmental Change (Sheet 3)
  - Predict and monitor reasonable (probabilistic) ranges of environmental changes (eco-climate, social, soil, landform processes)
  - Predict a system response to environmental change
  - Scale-up in time and space (including accelerated testing)
  - Integrate monitoring, modeling, and analogs into design, construction, operation, and maintenance

– Monitor and Evaluate System Performance (Sheet 4)
  - Conceptualize expected system performance and potential failure modes
  - Determine performance indicators (chemical, geophysical, biological) and failure criteria and methods of sensing/measuring
  - Determine optimal monitoring locations and frequencies
  - Design, install, and maintain systems to verify and monitor system performance and detect failure or indicators of failure
  - Accurately and realistically interpret monitoring data and analyze the consequences of system performance and potential failure

– Maintain System Performance (Sheet 5)
  - Identify and implement appropriate responses (what & how) to “failure” or change (repairs, corrections, retrofits, replacements)
  - Know when and where to make repairs, corrections, retrofits, and replacements
  - Determine and implement “routine maintenance” designs to nurture system performance
  - Identify and implement system improvements

– Communicate System Performance Info (Sheet 6)
  - Acquire and synthesize system performance data
  - Define and identify false “+” and false “-“ info
  - Identify user needs
  - Accurately and realistically explain monitoring, maintenance, and IC [institutional controls] needs; system performance; and potential consequences
  - Ensure universal, easy access over space, time, and audience
  - Immediate, integrated notification of potential “failure”

5. Issues/Concerns/Opportunities

- Incorporation of existing VZ [Vadose Zone] work
- Interfaces w/ other groups (monitoring)
- Impacts for "remediation" vs LTS

6. Actions

Complete initial "Target Forms" and e-mail to Jim/Doug	All	2/12
Vet/validate *[target forms]* by conference call	All	2/19
E-mail electronic "Target Form" to all WG members	Doug	1/31
WG Chairs meeting *[tentative]*	Jim	3/4&5

Responsible WG Member Doug Burns

SS&IC - LTS S&T Roadmap Target Form

Program Activity: Limit Contaminant Toxicity and Mobility

Technical Capability: Engineer Biogeochemical Environment

Goal: [H] Reduce Cost [H] Reduce Uncertainty [H] Reduce Risk

Short-term(2008) Target: (see below)

Target Description:

Cost -- Reduce volume of contaminated groundwater, and associated pump and treat costs, by 20% through improvements in the water's biogeochemical environment.

Uncertainty -- Reduce range of possible values associated with stability variables (e.g., toxicity, leachability, solubility, etc.) of risk driving contaminants at most DOE sites by 50%.

Risk -- Implement technologies that will detoxify or stablize the contaminants of concern in 5% of DOE's Contaminated waste, soil, and water.

Target Status: [ ] Process/Method Exists [X] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification:

Cost -- Methods being pursued include: Natural and accelerated Biological Remedication Project (contact: Dave Watson, ORNL, OST); EPA Site Program evaluating 16 NAPL sites; Geosyntec Consultants Work (contact: Dave Major): Subsurface Contamination Focus Area (SCFA) DNAPL analysis (contact: Brian Looney); INEEL Test Area North OU 1-07B bioremediation of TCE plume (contact: Kent Sorenson); and EPA Cincinnati Phytoremediation work (contact: Steve Rock)

Uncertainty -- Limited laboratory experimentation associated with waste stabilization has bee pursued but field scale demonstrations and verification of success are needed. Examples of limited work include Savannah River Site reducing work and Hanford MgO studies.

Risk -- Limited laboratory experimentation associated with waste stabilization has been pursued but field scale demonstrations and verification of success are needed.

Mid-term(2014) Target:

Target Description:

Target Status: [ ] Process/Method Exists [ ] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification:

Long-term(2020) Target:

Target Description:

Target Status: [ ] Process/Method Exists [ ] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification:

Compelling Reason/Rationale Discussion

Working Group: Contaminant Containment and Control

Activity: Limiting Contaminant Toxicity and Mobility

Capability: Engineering the Biogeochemical Environment

This capability involves developing science and technologies that will enable manipulation of subsurface biogeochemical processes in ways that limit the toxicity and mobility of contaminants. In other words, contaminants interact with subsurface environments in ways that are controlled by the physical characteristics and chemistry of both the contaminant and its surrounding subsurface environment. These interactions cause the contaminants to move through the subsurface at varying rates and affect living organisms to varying degrees. Development of processes that control these interactions would allow the Long Term Stewardship Program to fundamentally protect human health and the environment.

An improved ability to control the subsurface biogeochemical environment could lead to significant progress toward achieving all three of the Long Term Stewardship Roadmap goals (reducing cost, reducing uncertainty, and reducing risk). For example, successfully engineering subsurface biogeochemical environments would limit the volume of subsurface materials that could come into contact with contaminants and would therefore limit the volume of these materials that might require remediation. Reduced remediation would in turn lead to reduced costs. Similarly, an improved ability to control biogeochemical processes would lead to greater control of contaminant movement which would in turn lead to a reduction in uncertainty associated with predicting how contaminants move and how they affect living organisms. Finally, successfully controlling biogeochemical processes would reduce a contaminant's ability to come into contact with humans or the environment and would therefore lead to risk reduction and a greater degree of protection for human health and the environment.

There is significant room for improvement in environmental science's ability to control the subsurface biogeochemical environment. For example, significant improvements could be achieved through advances in at least three areas of scientific enquiry; coupled processes, heterogeneity, and scaling. Coupled processes refers to the interaction of chemical, biologic, and physical processes within the contaminant/subsurface environment system. A large amount of research into the fundamentals of each of these processes has been completed but there is relatively little understanding of how each of the processes affects the others. Heterogeneity refers to the complex nature of natural systems. Most models of contaminant movement and interaction with living organisms incorporate significant simplifications that eliminate the uncertainties produced by heterogeneities. These assumptions must be replaced before a complete understanding of how contaminants move through the subsurface can be developed. Finally, scaling refers to issues associated with applying the results of experiments conducted at the scale of individual geologic units contained in a laboratory setting to larger, more complex settings that are actually present in the environment. These issues will have to be overcome before many remediation solutions that appear to work in the laboratory can be successfully applied in the field.

Responsible WG Member Jody Waugh

SS&IC - LTS S&T Roadmap Target Form

Program Activity: Accommodate Environmental Change

Technical Capability: Integrate modeling, monitoring, and analogs into design, construction, operation, and maintenance

Goal: [H] Reduce Cost [H] Reduce Uncertainty [ ] Reduce Risk

Short-term(2008) Target: (see below)

Target Description:

Cost -- Reduce cost of long-term maintenance by greater than 50% through incorporation of performance modeling and monitoring approaches that accommodate reasonable projections of long-term change in the ecology, geomorphology, and climate of a site as estimated form analogs.

Uncertainty -- Reduce uncertainty in end-state projections 50% by inferring reasonable ranges of long-term change in the environmental settings of containment systems based on studies of natural and archeological analogs.

Target Status: [ ] Process/Method Exists [X] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification: Methods being pursued include: Long-Term Cover Design Guidance, Subsurface Contaminant Focus Area (SCFA, contact: Scott McMullin, SRS); Grand Junction Long-Term Surveillance and Maintenance (LTSM, contacts: Carl Jacobson and Jody Waugh, MACTEC-ERS); Hanford Protective Barrier Program (contact: Glendon Gee); INEEL cover design research (contacts: Doug Halford, Stoller; Tim Reynolds, TREC; Jay Anderson, Idaho State University); and Nevada Test Site long-term cover research (contact: David Shafer, Desert Research Institute)

Mid-term(2014) Target:

Target Description:

Target Status: [ ] Process/Method Exists [ ] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification:

Long-term(2020) Target:

Target Description:

Target Status: [ ] Process/Method Exists [ ] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification:

Responsible WG Member Jody Waugh

SS&IC - LTS S&T Roadmap Target Form

Program Activity: Limit Intrusion, Release, Transport, and Exposure

Technical Capability: Understand and mimic natural processes

Goal: [H] Reduce Cost [H] Reduce Uncertainty [H] Reduce Risk

Short-term(2008) Target: (see below)

Target Description:

Cost – Reduce disposal cell costs by 25% through incorporation of engineering approaches that imitate the geomorphology and ecology of natural settings exhibiting favorable attributes for long-term containment.

Uncertainty – Reduce conservatism in engineering design calculations by 25-50% based on the observed long-term stability and performance of natural systems.

Risk – Reduce likelihood of containment system failure and exposure risks 25% by incorporating (accommodating) Long-term system change in the design process.

Target Status: [ ] Process/Method Exists [X] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification:

Methods being pursued include: Long-Term Cover Design Guidance, Subsurface Contaminant Focus Area (SCFA, contact: Scott McMullin, SRS); Alternative Cover Assessment Program (ACAP), EPA National Risk Management Research Laboratory (contacts: Steve Rock, EPA; Craig Benson, University of Wisconsin; Bill Albright, Desert Research Institute); Hanford Protective Barrier Program (contact: Glendon Gee); INEEL cover design research (contacts: Doug Halford, Stoller; Tim Reynolds, TREC; Jay Anderson, Idaho State University); Grand Junction Long-Term Surveillance and Maintenance (LTSM, contacts: Carl Jacobson and Jody Waugh, MACTEC-ERS); Alternative Landfill Cover Demonstration (contact: Steve Dwyer, Sandia National Laboratory); and Nevada Test Site long-term cover research (contact: David Shafer, Desert Research Institute)

Mid-term(2014) Target:

Target Description:

Target Status: [ ] Process/Method Exists [ ] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification:

Long-term(2020) Target:

Target Description:

Target Status: [ ] Process/Method Exists [ ] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification:

Compelling Reason/Rationale Discussion

Working Group: Contaminant Containment and Control

Activities: 2.0. Limit Intrusion, Releases, Transport, and Exposure
3.0 Accommodate Environmental Change

Capabilities: 2.4 Understand and mimic natural processes.
3.4 Integrate monitoring, modeling, and analogs into design, construction, operation, and maintenance.

Relevence

Virtually every DOE site will require long-term isolation of contaminants in landfills, high-level waste tanks, and other facilities. Containment systems are needed to control contaminant migration for 100s to 1000s of years, and do so while natural processes are acting to mobilize contaminants. This is an unprecedented engineering challenge**.** Current design, performance monitoring, and performance assessment approaches fail to account for inevitable long-term changes in the environmental setting of containment systems.

Design. Existing design approaches rely on conventional engineering methods that disregard key aspects of environmental change. Typical designs are collections of prescribed physical barriers to known or perceived release pathways and are rarely evaluated as integrated systems. Limited field evaluations show that many existing containment and cover designs are failing to meet performance standards in the short term. In particular, biointrusion, desiccation, frost penetration, and other soil development processes have increased permeability of compacted soil layers and other resistive materials intended to last for hundreds of years.

Performance Monitoring. Monitoring will be required to both verify containment system performance in the short term (demonstrate that an installation achieved specific performance goals), and to monitor for long-term performance (to monitor early-warnings of responses to changes in the environmental setting, and to reiterate and refine performance and risk reduction projections). Most existing and proposed performance monitoring schemes rely on arrays of point sensors that will likely need to be replaced within ten years. These current systems are unproven and will be costly in the long term.

Performance Predictions. Current performance assessment approaches implicitly assume that long-term environmental changes can be captured with numerical extrapolations based on a few years of monitoring ambient conditions in field tests. The UMTRA stewardship project and others are finding that the performance of engineered covers will change in ways that cannot be predicted using numerical models and short-term field data.

Need and Objectives

A capability is needed for accommodating long-term environmental change using an approach that integrates *natural analogs* into the design, construction, modeling, and monitoring of containment systems. This approach will link existing engineering with natural science methodologies in an "ecosystem engineering" framework. The development of this capability will focus on the following objectives:

1. Understand and characterize possible long-term changes in the environmental setting that will impacting containment system performance ("failure mechanisms") such as climate change, geomorphological processes, soil development (pedogenesis), and ecological succession.

2. Design sustainable containment systems that mimic the geomorphology, soils, and ecology of natural settings exhibiting favorable attributes for long-term containment (e.g. long-term stability and a favorable water balance). Existing short-term studies of alternative cover designs that rely on a soil "sponge" layer to store precipitation and plants to seasonally return it to the atmosphere ("ET covers") are a step in the right direction.
3. Develop a methodology for projecting long-term performance of containment systems that links natural analogs with field tests (e.g. lysimetry) and predictive models. Reductions in uncertainty can be achieved by characterizing natural analogs for evidence of the long-term evolution of disposal cell geometry, soil materials, and ecosystems. Such evidence can be used to impose reasonable ranges of environmental conditions during field tests, and to define possible end-state inputs to numerical simulations.
4. Develop design verification and monitoring tools that target early-warning of potential changes in system performance based on an understanding of the evolution of the environmental setting. In particular, new tools are needed for remote sensing (large-scale measurement) of natural indicators of change (e.g. phytomonitoring).

Responsible WG Member Ellen Smith

LTS S&T Roadmap Target Form

Program Activity: Accommodate environmental change (in CC&C systems)

Technical Capability: Predict system responses to environmental change

Goal: [H] Reduce Cost [H] Reduce Uncertainty [ ] Reduce Risk

Short-term(2008) Target: (see below)

Target Description:

Cost -- Improved predictive capability allows reduction in routine monitoring costs by assisting in identifying key targets to monitor and allows less frequent repair/replacement of caps/covers and other engineered systems by allowing more reliable prediction of time to failure. These improvements reduce long-term stewardship costs by a large amount at most DOE sites with caps and covers.

Uncertainty -- Improved prediction of time to failure and characteristics of "failed" system, for caps, covers, and engineered waste forms, leads to 50% reduction in range of uncertainty in predicting long-term consequences at most DOE sites.

Target Status: [ ] Process/Method Exists [X] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification: Experimental cover/cap systems exist that could be monitored and tested, and natural/historical/archaeological analogues exist for some cap/cover systems and engineered waste forms. Furthermore, general knowledge of the processes that affect CC&C systems (including ecological succession, seismic effects on earth structures , erosion, pedogenesis, and other natural processes) exists and could be applied.

Some specific cap/cover projects that offer opportunities for needed monitoring and testing are:

- Long-Term Cover Design Guidance, Subsurface Contaminant Focus Area (SCFA), (contact: Scott McMullin, SRS)
- Alternative Cover Assessment Program (ACAP), EPA National Risk Management Research Laboratory (contacts: Steve Rock, EPA; Craig Benson, University of Wisconsin; Bill Albright, Desert Research Institute
- Hanford Protective Barrier Program (contact: Glendon Gee)
- INEEL cover design research (contacts: Doug Halford, Stoller; Tim Reynolds, TREC; Jay Anderson, Idaho State University)
- Grand Junction Long-Term Surveillance and Maintenance (LTSM), (contacts: Carl Jacobson and Jody Waugh, MACTEC-ERS)
- Alternative Landfill Cover Demonstration (contact: Steve Dwyer, Sandia National Laboratory)
- Nevada Test Site long-term cover research (contact: David Shafer, Desert Research Institute)
- Vanderbilt University/Consortium for Risk Evaluation with Stakeholder Participation (contact: Frank Parker, Jim Clarke)

Mid-term(2014) Target:

Target Description:

Target Status: [ ] Process/Method Exists [ ] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification: Various studies on Radiation Effects in Nuclear Waste Materials

Long-term(2020) Target:

Target Description:

Target Status: [ ] Process/Method Exists [ ] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification:

Compelling Reason/Rationale Discussion

Working Group: Contaminant Containment and Control

Activity: Accommodate environmental change (*in CC&C systems*)

Capability: Predict system responses to environmental change

Discussion

Long-term stewardship for closure sites includes periodic inspection and various types of monitoring to detect failures. Furthermore, when failure occurs or is suspected, managers would need to repair or replace systems that failed or are suspected to have failed. Most conventional CC&C designs have not been designed or tested for long-term survivability, with the result that DOE must plan for aggressive long-term stewardship programs to provide needed assurance of their effectiveness.

Improved capability to predict system responses to various expected or potential environmental changes could, by 2008, substantially reduce both costs and uncertainty of long-term stewardship for sites with engineered caps/covers. This capability could lead to substantial reductions in routine inspection/monitoring costs by assisting in identifying key targets to monitor and allowing less frequent or extensive repair/replacement, both by allowing more reliable prediction of time to failure and by identifying the specific systems potentially requiring repair. Cost savings would be greatest where R&D is available in time to be reflected in modifications to final closure designs. Also, improved prediction of time to failure and characteristics of "failed" system, for caps, covers, and engineered waste forms could lead in the near term to a 50% reduction in range of uncertainty in predicting long-term consequences at most DOE sites.

Experimental cover/cap systems exist that could be monitored and tested over the next 5 years and beyond to develop improved understanding (and thus prediction) of their responses to climatic cycling and biological processes. Also, natural/historical/archaeological analogues (such as Indian mounds and old concrete) exist for some cap/cover systems and engineered waste forms and can be a source of observations on the effect of less-frequent phenomena (such as earthquakes) and longer time periods. Furthermore, general knowledge of the processes that affect CC&C systems (including ecological succession, seismic effects on earth structures , erosion, pedogenesis, and other natural processes) exists and could be applied in predicting long-term performance of these systems.

Responsible WG Member Ellen Smith

LTS S&T Roadmap Target Form

Program Activity: Maintain system performance (of CC&C systems)

Technical Capability: Determine and implement "routine maintenance" designed to nurture system performance

Goal: [H] Reduce Cost [ ] Reduce Uncertainty [H] Reduce Risk

Short-term(2008) Target:

Target Description: Optimized protocols for maintenance of cap and cover systems reduce life-cycle maintenance costs by >$1M at most DOE sites~~, reduce exposure to maintenance workers, and reduce exposure to the public by avoiding/delaying failures that could lead to undetected releases~~. Improved understanding of maintenance needs for natural attenuation and reactive barriers allows similar improvements respecting cost for long-term site maintenance of these systems.

Target Status: [ ] Process/Method Exists [X] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification: Various "ET cap" projects include vegetation management protocols to enhance desirable ecological succession on arid and semi-arid sites. Basic science exists to extend similar concepts (but not these specific approaches) to humid sites. Various ongoing test applications of natural attenuation and reactive barriers provide opportunities to answer questions about optimum maintenance for these systems (such as interventions to add nutrients, air, etc., and natural phenomena that have positive effects on performance).

Some specific cap/cover projects that include or could include evaluation of measures to enhance desirable ecological succession are:

- Long-Term Cover Design Guidance, Subsurface Contaminant Focus Area (SCFA), (contact: Scott McMullin, SRS)
- Alternative Cover Assessment Program (ACAP), EPA National Risk Management Research Laboratory (contacts: Steve Rock, EPA; Craig Benson, University of Wisconsin; Bill Albright, Desert Research Institute
- Hanford Protective Barrier Program (contact: Glendon Gee)
- INEEL cover design research (contacts: Doug Halford, Stoller; Tim Reynolds, TREC; Jay Anderson, Idaho State University)
- Grand Junction Long-Term Surveillance and Maintenance (LTSM), (contacts: Carl Jacobson and Jody Waugh, MACTEC-ERS)
- Alternative Landfill Cover Demonstration (contact: Steve Dwyer, Sandia National Laboratory)
- Nevada Test Site long-term cover research (contact: David Shafer, Desert Research Institute)

Mid-term(2014) Target:

Target Description:

Target Status: [ ] Process/Method Exists [ ] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification:

Long-term(2020) Target:

Target Description:

Target Status: [ ] Process/Method Exists [ ] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification:

Compelling Reason/Rationale Discussion

Working Group: Contaminant Containment and Control

Activity: Maintain system performance *(of CC&C systems)*

Capability: Determine and implement "routine maintenance" designed to nurture system performance

Discussion

Routine maintenance, including measures such as periodic inspection, mowing of vegetation, and replacement or repair of components, is a major component of long-term stewardship efforts and costs for most DOE sites targeted for remedial action before 2008, including new waste-disposal cells, capped/entombed facilities and contamination zones, and many groundwater plumes. The default technologies for most closures depend on intensive maintenance for their effectiveness, including frequent mowing and other measures to maintain artificial biological conditions on the site, continued groundwater pumping and treatment, and/or frequent intervention to repair cracked or eroded barrier layers.

Development of closure designs and maintenance protocols that accommodate and take advantage of natural processes (instead of continually combatting them) could substantially reduce long-term stewardship costs. Health risks to workers would be reduced by reduced need for active intervention, and potential long-term risks to the public would be reduced if the natural robustness of containment and control systems were improved (less risk to the public in the event that maintenance efforts lapse).

Optimized protocols for maintenance of cap and cover systems easily could reduce life-cycle maintenance costs by >$1M at most DOE sites. Improved understanding of maintenance needs for natural attenuation and reactive barrier could allow similar improvements respecting cost for long-term site maintenance of these systems. Reductions in potential risk in the event of a future lapse in maintenance activities would be large (thus addressing an area of regulatory and stakeholder concern).

Multiple technical approaches exist for addressing this objective, depending on the CC&C technology and ecosystem. In arid and semi-arid climates, evidence is being developed regarding natural vegetation communities that could enhance long-term performance of engineered caps/covers, as well as means to encourage establishment of such vegetation. Research on natural attenuation, bioremediation, and permeable-reactive-barrier treatment of groundwater contamination has the potential to lead to recommendations on measures (such as interventions to introduce or allow the natural introduction of air or nutrients) to maintain geochemical environments or stimulate microbial communities that are conducive to these processes. Potential also exists to (1) identify humid-region vegetation succession patterns that would be compatible with cap/cover survival and would require less maintenance than mowed grass (for sites such as Fernald, Oak Ridge, and Savannah River), (2) incorporate phytoremediation into long-term maintenance protocols, (3) promote development of contaminant-trapping wetlands at potential groundwater discharge locations, and (4) stimulate "self healing" of barrier layers.

Continued investment in existing R&D efforts and pursuit of new initiatives in this area could produce significant cost reductions by 2008, particularly if new concepts are retrofit into the closure designs and maintenance plans for sites being closed during this near-term period.

Responsible WG Member Ellen Smith

LTS S&T Roadmap Target Form

Program Activity: Limit contaminant toxicity and mobility

Technical Capability: Understand contaminant thermo-bio-geochemical interactions (including redox, partition coefficients, time dependence, and coupled processes)

Goal: [ ] Reduce Cost [H] Reduce Uncertainty [ ] Reduce Risk

Short-term(2008) Target:

Target Description: Improved understanding allows major reduction in uncertainty in predicting long-term risks at one or more major DOE sites (tank-closure, contaminated-soil, or groundwater-contamination), allowing key remedial projects to move forward due to new confidence regarding their long-term implications.

Target Status: [ ] Process/Method Exists [X] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification: Extensive knowledge exists on the chemistry of the contaminants of concern at DOE sites, but much remains unknown regarding interactions between chemical constituents, interactions with the geologic setting, effects of biological processes, time dependence of processes, and coupling between thermal, chemical, radiological, and biological processes. Lack of critical information on interactions creates large uncertainty in predicting the long-term behavior of planned and proposed remediation schemes, with the result either that remediation cannot proceed due to concerns about long-term effectiveness, or that remedial measures must be overdesigned for conservatism. Resolution of uncertainties would primarily involve extension of existing knowledge to specific systems of concern for DOE.

Examples:

- Determination of the redox chemistry of uranium or chromium in a particular disposal setting could lead to 10-fold or greater reduction of uncertainty in predicting long-term consequences.
- Improved understanding of the chemical behavior of technetium in grout waste forms could substantially reduce the uncertainty about the long-term risk from closure of the Savannah River high-level waste tanks.
- Improved knowledge of the expected behavior of contaminants in a wide range of site-specific disposal or in-situ stabilization settings would assist in interpreting the implications of "hits" observed in post-closure monitoring results.

Mid-term(2014) Target:

Target Description:

Target Status: [ ] Process/Method Exists [ ] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification:

Long-term(2020) Target:

Target Description:

Target Status: [ ] Process/Method Exists [ ] Process/Method Being Pursued [ ] No Known Process/Method

Status Justification:

Compelling Reason/Rationale Discussion

Working Group: Contaminant Containment and Control

Activity: Limit contaminant toxicity and mobility

Capability: Understand contaminant thermo-bio-geochemical interactions (including redox, partition coefficients, time dependence, and coupled processes)

Discussion

Extensive knowledge exists on the chemistry of the contaminants of concern at DOE sites, but much remains unknown regarding interactions between chemical constituents, interactions with the geologic setting, effects of biological processes, time dependence of processes, and coupling between thermal, chemical, radiological, and biological processes. Lack of critical information on interactions creates large uncertainty in predicting the long-term behavior of planned and proposed remediation schemes, with the result either that remediation cannot proceed due to concerns about long-term effectiveness, or that remedial measures must be overdesigned for conservatism. Resolution of uncertainties would primarily involve extension of existing knowledge to specific systems of concern for DOE. (For example, determination of the redox chemistry of uranium or chromium in a particular disposal setting could lead to 10-fold or greater reduction of uncertainty in predicting long-term consequences.)

Examples:
Where uranium or chromium are contaminants of concern, determination of the pH/redox chemistry of uranium or chromium in the disposal or stabilization setting could lead to 10-fold or greater reduction of uncertainty in predicting long-term consequences.
Improved understanding of the chemical behavior of technetium in grout waste forms could substantially reduce the uncertainty about the long-term risk from closure of the Savannah River high-level waste tanks, potentially making it easier to move forward with tank closure.
Improved knowledge of the expected behavior of contaminants in a wide range of site-specific disposal or in-situ stabilization settings would assist in interpreting the implications of any "hits" observed in post-closure monitoring results.

Activities / Capabilities	Impact by 2008	Impact beyond 2008	Targets: Short-term (2008)	Targets: Mid-term (2014)	Targets: Long-term (2020)	Resp. WG Member	
1 Limit Contaminant Toxicity & Mobility							
1.1 Understand contaminant/biogeochemical/thermal interactions (redox, partition coefficients, time dependence, coupled processes)							
G1: reduce cost	M-H	M-H					
G2: reduce technical uncertainty	**H**					Smith	
G3: reduce risk to public and environment	L-M						
1.2 Scale from laboratory to field-scale							
G1: reduce cost	M						
G2: reduce technical uncertainty	M						
G3: reduce risk to public and environment	M						
1.3 Predict and verify system effectiveness							
G1: reduce cost	M-H						
G2: reduce technical uncertainty	**H**	H				Waters	
G3: reduce risk to public and environment	M						
1.4 Engineer biogeochemical environment							
G1: reduce cost	**H**		Reduce P&T volume/cost by 20%			Burns	Reduce the volume (and corresponding cost) of contaminated ground water requiring pump-n-treat by 20%
G2: reduce technical uncertainty	**H**		Reduce range of uncertainty 50%			Burns	Reduce range of uncertainty associated with risk driving contaminants (toxicity, leachability, solubility, volitility, mechanical properties) by 50%
G3: reduce risk to public and environment	**H**		Technologies to detoxify 5% toxic substances			Burns	Technologies to detoxify or stabilize 5% of the toxic substances in waste, contaminated soil, and ground water.
1.5 Deliver stabilizing and detoxification agents							
G1: reduce cost	**H**					Dunn	
G2: reduce technical uncertainty	**H**					Dunn	
G3: reduce risk to public and environment	**H**					Dunn	
2 Limit Intrusion, Release, Transport, & Exposure							
2.1 Understand and characterize site-specifc intrusion, release, transport, and exposure (including movement through heterogeneous systems)							
G1: reduce cost	M						
G2: reduce technical uncertainty	**H**					MacDonell	
G3: reduce risk to public and environment	M						
2.2 Design, build, and operate CC&C systems (e.g., pump & treat, funnel & gate, surface/subsurface barriers, design-to-failure points, etc.)							
G1: reduce cost	**H**					Dunn	
G2: reduce technical uncertainty	**H**					Dunn	
G3: reduce risk to public and environment	**H**					Dunn	
2.3 Scale-up in space & time (including accelerated testing)							
G1: reduce cost	M						
G2: reduce technical uncertainty	M						
G3: reduce risk to public and environment	M						
2.4 Understand and mimic natural processes.							
G1: reduce cost	**H**		Reduce disposal cell costs by 25%			Waugh	
G2: reduce technical uncertainty	**H**		Reduce conservatism in engineering design calculations by 25-50%			Waugh	
G3: reduce risk to public and environment	**H**		Reduce likelihood of containment system failure and exposure 25%			Waugh	
3 Accommodate Environmental Change							
3.1 Predict and monitor reasonable (probablistic) ranges of environmental change (eco-, climate, social, soil, landform processes)							
G1: reduce cost	M						
G2: reduce technical uncertainty	**H**					MacDonell	
G3: reduce risk to public and environment	L						
3.2 Predict system reponse to environmental change							
G1: reduce cost	**H**		Reduce routine monitoring costs and allow for less frequent repair of caps/covers and other engineered systems			Smith	
G2: reduce technical uncertainty	**H**		50% reduction in range of uncertainty in predicting long-term consequences			Smith	
G3: reduce risk to public and environment	M						

3.3 Scale-up in space & time (including accelerated testing)						
G1: reduce cost	M					
G2: reduce technical uncertainty	**H**					Burns
G3: reduce risk to public and environment	M					
3.4 Integrate monitoring, modeling, and analogues into design, construction, operation, and maintenance.						
G1: reduce cost	**H**		Reduce cost of long-term maintenance by > 50%			Waugh
G2: reduce technical uncertainty	**H**		Reduce uncertainty of end-state projections by 50%			Waugh
G3: reduce risk to public and environment	M					
4 Monitor & Evaluate System Performance						
4.1 Conceptualize expected system performance and potential failure modes						
G1: reduce cost	**H**					Clarke
G2: reduce technical uncertainty	M					
G3: reduce risk to public and environment	**H**					Clarke
4.2 Determine performance indicators, failure criteria, and methods of sensing/measuring (chemical, geophysical, biological)						
G1: reduce cost	**H**					Clarke
G2: reduce technical uncertainty	M					
G3: reduce risk to public and environment	M					
4.3 Determine optimal monitoring locations and frequencies						
G1: reduce cost	**H**					Clarke
G2: reduce technical uncertainty	M-H					
G3: reduce risk to public and environment	M					
4.4 Design, install, and maintain systems to verify and monitor system performance and to predict failure or indicators of failure						
G1: reduce cost	**H**					Clarke
G2: reduce technical uncertainty	**H**					Clarke
G3: reduce risk to public and environment	M					
4.5 Accurately and realistically interpret monitoring data and analyse the consequences of sytem performance and potential failure						
G1: reduce cost	M					
G2: reduce technical uncertainty	**H**					Clarke
G3: reduce risk to public and environment	M					
5 Maintain System Performance						
5.1 Identify and implement appropriate responses (what & how) to change and "failure" (repairs, corrections, retrofits, replacements)						
G1: reduce cost	**H**					MacDonell
G2: reduce technical uncertainty	M					
G3: reduce risk to public and environment	M					
5.2 Know when and where to to make repairs, corrections, retrofits, replacements						
G1: reduce cost	**H**					MacDonell
G2: reduce technical uncertainty	M					
G3: reduce risk to public and environment	M					
5.3 Determine & implement "routine maintenance" designed to nurture system performance						
G1: reduce cost	**H**		Reduce life-cycle maintenance costs by >$1M at most DOE sites			Smith
G2: reduce technical uncertainty	M					
G3: reduce risk to public and environment	**H**		Reduce exposure to maintenance workers and the public by avoiding/ delaying failures that could lead to undetected releases			Smith
5.4 Identify & implement sytems improvements						
G1: reduce cost	M					
G2: reduce technical uncertainty	M					
G3: reduce risk to public and environment	M					
6 Communicate System Performance Information						
6.1 Acquire & synthesize system performance data						
G1: reduce cost	M					
G2: reduce technical uncertainty	L					
G3: reduce risk to public and environment	L					
6.2 Define & identify false positives and false negatives						

G1: reduce cost	**H**					Burns
G2: reduce technical uncertainty	M					
G3: reduce risk to public and environment	M					
6.3 Identify user needs						
G1: reduce cost	M-H					
G2: reduce technical uncertainty	L					
G3: reduce risk to public and environment	L					
6.4 Accurately & realistically explain monitoring, maintenance, and institutional control needs; system performance; and potential consequences						
G1: reduce cost	M-H					
G2: reduce technical uncertainty	L					
G3: reduce risk to public and environment	M					
6.5 Ensure universal, easy access over space, time, and audience						
G1: reduce cost	M					
G2: reduce technical uncertainty	L					
G3: reduce risk to public and environment	M-H					
6.6 Provide immediate, integrated notification of potential "failure"						
G1: reduce cost	M					
G2: reduce technical uncertainty	M					
G3: reduce risk to public and environment	M-H					
7 Improve System Designs						
7.1 Self-healing / self-correcting systems						
7.2 Designs that facilitate repair						
7.3 "Smart" storage -- combine treatment and containment						

Contamination Containment and Control

Work Group Members

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Preamble

CC&C systems have evolved over the past 30 years or so. Our experience with their performance in very limited and we have had to rely on analytical forecasting techniques (models) which reflect an incomplete understanding of important processes and conditions, and which necessarily have a high degree of uncertainty.

At present we have no CC&C system technologies that eliminate the need for stewardship activities given the very long times over which effective performance is needed.

Also, design approaches are not integrated with necessary stewardship activities, especially monitoring for early signs of undesirable events that could affect system performance and facilitation of needed responses.

Our challenge is to be able to make what we have implemented work, to the extent possible, and to develop better approaches to the design and implementation of future systems. Ideally, we will identify research that will impact both of these objectives.

Starting Points

- System design approaches will be **integrated**, not only with respect to the system components themselves, but also with respect to factors needed for effective stewardship such as monitoring, maintenance, and institutional controls.
- System designs will be driven by an understanding of **natural site-specific processes** that will affect future system performance and will be informed by an understanding of interactions with human systems.
- Assumptions will be replaced with increased understanding and corresponding increasing **reliability of analytical forecasting methods**, such as performance and risk assessments.
- **Likelihoods, consequences, and response costs** for events that could affect system performance will be understood quantitatively and will be factored into remediation decision making.
- **Indicators of early stages of undesired events** will be known and used to design monitoring and response approaches.
- Information management system will be in place so that **knowledge about system performance** can be shared.

CC&C Working Group Vision Statement

Over the long term … Implement CC&C systems, integrated with LTS needs, to enable effective stewardship and reduce cost and risk for future generations.

By 2008 … CC&C systems will (1) incorporate analysis of events that compromise system integrity, early indicators of change, and appropriate response actions; (2) incorporate an understanding of natural process that can affect future performance; and (3) integrate engineered, natural, and human systems and incorporate new info over time.

Activities

- **Limit contaminant toxicity and mobility**
- **Limit intrusion, release, transport, and exposure**
- **Accommodate environmental change**
- **Monitor and evaluate system performance**
- **Maintain system performance**
- **Communicate system performance information**
- **Improve system designs**

CC&C - Activity 1

Activities / Capabilities	Impact by 2008	Impact beyond 2008	Targets: Short-term (2008)	Mid-term (2014)	Long-term (2020)
1 Limit Contaminant Toxicity & Mobility					
1.1 Understand contaminant/biogeochemical/thermal interactions (redox, partition coefficients, time dependence, coupled processes)					
G1: reduce cost	M-H	M-H			
G2: reduce technical uncertainty	H				
G3: reduce risk to public and environment	L-M				
1.2 Scale from laboratory to field-scale					
G1: reduce cost	M				
G2: reduce technical uncertainty	M				
G3: reduce risk to public and environment	M				
1.3 Predict and verify system effectiveness					
G1: reduce cost	M-H				
G2: reduce technical uncertainty	H	H			
G3: reduce risk to public and environment	M				
1.4 Engineer biogeochemical environment					
G1: reduce cost	H		Reduce P&T volume/cost by 20%		
G2: reduce technical uncertainty	H		Reduce range of uncertainty 50%		
G3: reduce risk to public and environment	H		Technologies to detoxify 5% toxic substances		
1.5 Deliver stabilizing and detoxification agents					
G1: reduce cost	H				
G2: reduce technical uncertainty	H				
G3: reduce risk to public and environment	H				

CC&C - Activity 2

Activities / Capabilities	Impact by 2008	Impact beyond 2008	Targets: Short-term (2008)	Mid-term (2014)	Long-term (2020)
2 Limit Intrusion, Release, Transport, & Exposure					
2.1 Understand and characterize site-specifc intrusion, release, transport, and exposure (including movement through heterogeneous systems)					
G1: reduce cost	M				
G2: reduce technical uncertainty	H				
G3: reduce risk to public and environment	M				
2.2 Design, build, and operate CC&C systems (e.g., pump & treat, funnel & gate, surface/subsurface barriers, design-to-failure points, etc.)					
G1: reduce cost	H				
G2: reduce technical uncertainty	H				
G3: reduce risk to public and environment	H				
2.3 Scale-up in space & time (including accelerated testing)					
G1: reduce cost	M				
G2: reduce technical uncertainty	M				
G3: reduce risk to public and environment	M				
2.4 Understand and mimic natural processes.					
G1: reduce cost	H				
G2: reduce technical uncertainty	H				
G3: reduce risk to public and environment	H				

CC&C - Activity 3

Activities / Capabilities	Impact by 2008	Impact beyond 2008	Targets: Short-term (2008)	Mid-term (2014)	Long-term (2020)
3 Accommodate Environmental Change					
3.1 Predict and monitor reasonable (probablistic) ranges of environmental change (eco-, climate, social, soil, landform processes)					
G1: reduce cost	M				
G2: reduce technical uncertainty	H				
G3: reduce risk to public and environment	L				
3.2 Predict system reponse to environmental change					
G1: reduce cost	H				
G2: reduce technical uncertainty	H				
G3: reduce risk to public and environment	M				
3.3 Scale-up in space & time (including accelerated testing)					
G1: reduce cost	M				
G2: reduce technical uncertainty	H				
G3: reduce risk to public and environment	M				
3.4 Integrate monitoring, modeling, and analogues into design, construction, operation, and maintenance.					
G1: reduce cost	H				
G2: reduce technical uncertainty	H				
G3: reduce risk to public and environment	M				

CC&C - Activity 4

Activities / Capabilities	Impact by 2008	Impact beyond 2008	Targets: Short-term (2008)	Mid-term (2014)	Long-term (2020)
4 Monitor & Evaluate System Performance					
4.1 Conceptualize expected system performance and potential failure modes					
G1: reduce cost	H				
G2: reduce technical uncertainty	M				
G3: reduce risk to public and environment	H				
4.2 Determine performance indicators, failure criteria, and methods of sensing/measuring (chemical, geophysical, biological)					
G1: reduce cost	H				
G2: reduce technical uncertainty	M				
G3: reduce risk to public and environment	M				
4.3 Determine optimal monitoring locations and frequencies					
G1: reduce cost	H				
G2: reduce technical uncertainty	M-H				
G3: reduce risk to public and environment	M				
4.4 Design, install, and maintain systems to verify and monitor system performance and to predict failure or indicators of failure					
G1: reduce cost	H				
G2: reduce technical uncertainty	H				
G3: reduce risk to public and environment	M				
4.5 Accurately and realistically interpret monitoring data and analyse the consequences of sytem performance and potential failure					
G1: reduce cost	M				
G2: reduce technical uncertainty	H				
G3: reduce risk to public and environment	M				

CC&C - Activity 5

Activities / Capabilities	Impact by 2008	Impact beyond 2008	Targets: Short-term (2008)	Mid-term (2014)	Long-term (2020)
5 Maintain System Performance					
5.1 Identify and implement appropriate responses (what & how) to change and "failure" (repairs, corrections, retrofits, replacements)					
G1: reduce cost	H				
G2: reduce technical uncertainty	M				
G3: reduce risk to public and environment	M				
5.2 Know when and where to to make repairs, corrections, retrofits, replacements					
G1: reduce cost	H				
G2: reduce technical uncertainty	M				
G3: reduce risk to public and environment	M				
5.3 Determine & implement "routine maintenance" designed to nurture system performance					
G1: reduce cost	H				
G2: reduce technical uncertainty	M				
G3: reduce risk to public and environment	H				
5.4 Identify & implement sytems improvements					
G1: reduce cost	M				
G2: reduce technical uncertainty	M				
G3: reduce risk to public and environment	M				

CC&C - Activity 6

Activities / Capabilities	Impact by 2008	Impact beyond 2008	Targets: Short-term (2008)	Mid-term (2014)	Long-term (2020)
6 Communicate System Performance Information					
6.1 Acquire & synthesize system performance data					
G1: reduce cost	M				
G2: reduce technical uncertainty	L				
G3: reduce risk to public and environment	L				
6.2 Define & identify false positives and false negatives					
G1: reduce cost	H				
G2: reduce technical uncertainty	M				
G3: reduce risk to public and environment	M				
6.3 Identify user needs					
G1: reduce cost	M-H				
G2: reduce technical uncertainty	L				
G3: reduce risk to public and environment	L				
6.4 Accurately & realistically explain monitoring, maintenance, and institutional control needs; system performance; and potential consequences					
G1: reduce cost	M-H				
G2: reduce technical uncertainty	L				
G3: reduce risk to public and environment	M				
6.5 Ensure universal, easy access over space, time, and audience					
G1: reduce cost	M				
G2: reduce technical uncertainty	L				
G3: reduce risk to public and environment	M-H				
6.6 Provide immediate, integrated notification of potential "failure"					
G1: reduce cost	M				
G2: reduce technical uncertainty	M				
G3: reduce risk to public and environment	M-H				

CC&C - Activity 7

Long-Term Stewardship Science and Technology Roadmap

Activities / Capabilities	Impact by 2008	Impact beyond 2008	Targets: Short-term (2008)	Targets: Mid-term (2014)	Targets: Long-term (2020)
7 Improve System Designs					
7.1 Self-healing / self-correcting systems					
7.2 Designs that facilitate repair					
7.3 "Smart" storage -- combine treatment and containment					